eDof(Extend Depth of Field)

Wang Wei (May 30, 2024)

1 INTRODUCTION

China represents the most fiercely competitive market for smartphones globally, with mobile photography being a critical feature(see Fig. 1). Since 2023, leading smartphone manufacturers have increasingly focused on telephoto photography capabilities. Despite continuous advancements in optical lenses and sensors, the limited depth of field often prevents the subject from being fully captured. Extend Depth of Field (eDof) technology addresses this issue by analyzing the sequence of images captured during continuous zoom of a smartphone lens, extracting the relatively clear regions from each frame, and then combining these regions based on their positions to form a new image with full depth of field.

长焦微距
微观巨现
微小世界，放大震撼。家中萌宠的光泽绒毛、水中游弋的多彩小鱼、孔雀羽毛的惊艳纹理，无论亮光或暗光环境，都能清晰呈现，大放异彩。
1X参照
3.5X
3.5X
微小世界，大放异彩
发现美食、昆虫和花朵的惊艳细节，
记录微小世界的大震撼。
XIAOMI 14 ULTRA
75mm f/1.8 1/100s ISO160

Fig. 1. Promotional materials from smartphone companies like Xiaomi.

Figure 2 demonstrates the eDof technology I designed and developed, featured in the Xiaomi 14 Ultra, the highest-end flagship model released at the end of February this year. The native camera UI (at the top of the preview frame) allows consumers to switch to the "Depth Extension" mode with a tap. Once the user clicks the shutter button, it takes just 0.7 seconds to capture a sequence of seven 4K images at different focal points and synthesize a full-depth image.

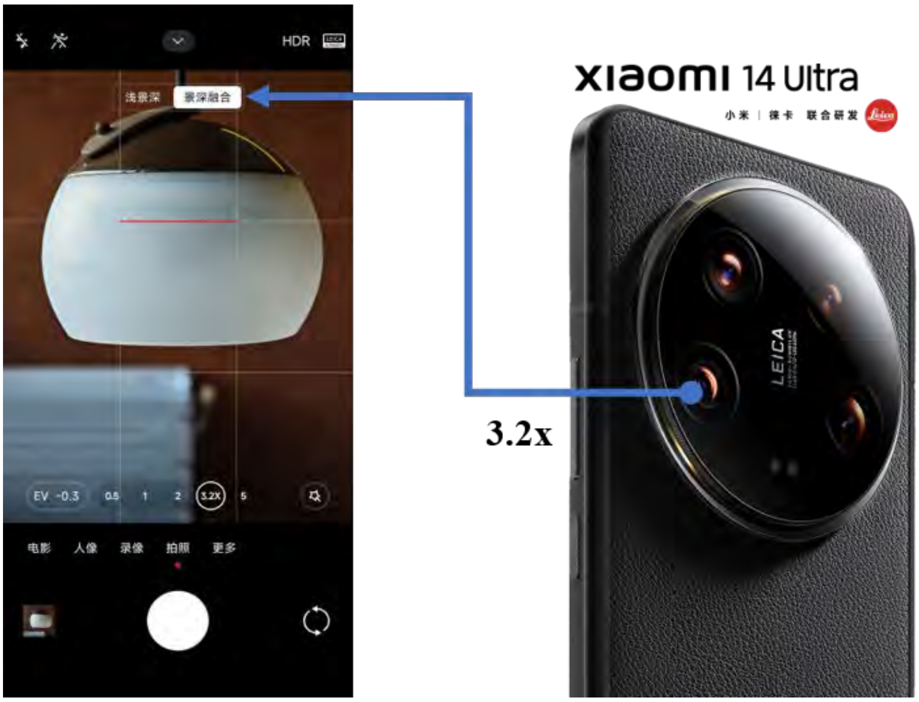


Fig. 2. Camera interface of Xiaomi 14 Ultra demonstrating the eDof technology.

2 FRAMEWORK

Within a brief three-month period (August to November 2023), the entire pipeline was designed, programmed, tested, optimized, and launched from scratch. Due to commercial competition restrictions, Figure 3 only provides a rough overview of the eDof process. The entire eDof pipeline includes three main modules: an optical flow-based image registration model (0.45s), a monocular depth detection model (0.12s), and a clarity detection module (0.21s). The image registration training data uses the inference results of large models such as RAFT[1] as ground truth for both unsupervised and supervised learning, while the monocular depth detection model uses the inference results of the Marigold[2] model as partial ground truth.

Figure 4 illustrates the input frames and the final synthesized full-depth image of the eDof algorithm.

Figure 5 compares our eDof algorithm with Photoshop, showing that in over 1000 sets of images across more than 30 scenes, our algorithm significantly outperforms Photoshop in terms of clarity detection accuracy, edge transitions, and time performance (Photoshop often requires around 30 seconds for seven 4K images, excluding image import time).

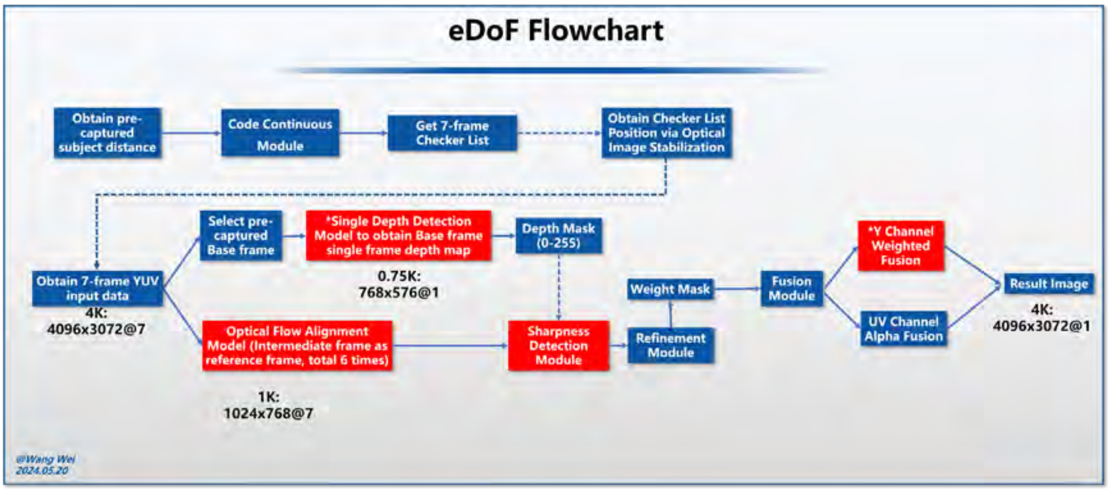

eDoF Flowchart
Obtain pre-captured subject distance
Code Continuous Module
Get 7-frame Checker List
Obtain Checker List Position via Optical Image Stabilization
Obtain 7-frame YUV input data
4K: 4096x3072@7
Select pre-captured Base frame
*Single Depth Detection Model to obtain Base frame single frame depth map
0.75K: 768x576@1
Depth Mask (0-255)
Optical Flow Alignment Model (Intermediate frame as reference frame, total 6 times)
1K: 1024x768@7
Sharpness Detection Module
Weight Mask
Refinement Module
Fusion Module
*Y Channel Weighted Fusion
UV Channel Alpha Fusion
Result Image
4K: 4096x3072@1
@Wang Wei 2024.05.20

Fig. 3. Overview of the eDof scheme.

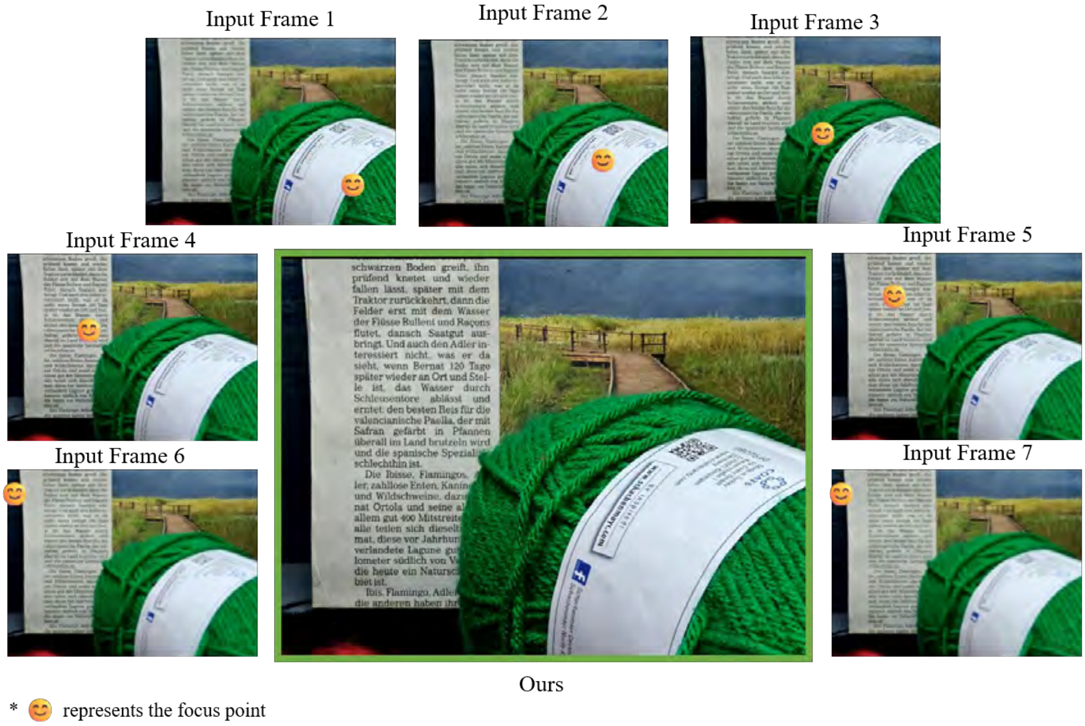

Input Frame 1
Input Frame 2
Input Frame 3
Input Frame 4
Input Frame 5
Input Frame 6
Input Frame 7
Ours
* 😊 represents the focus point

Fig. 4. Input frames and the synthesized full-depth image of the eDof algorithm.

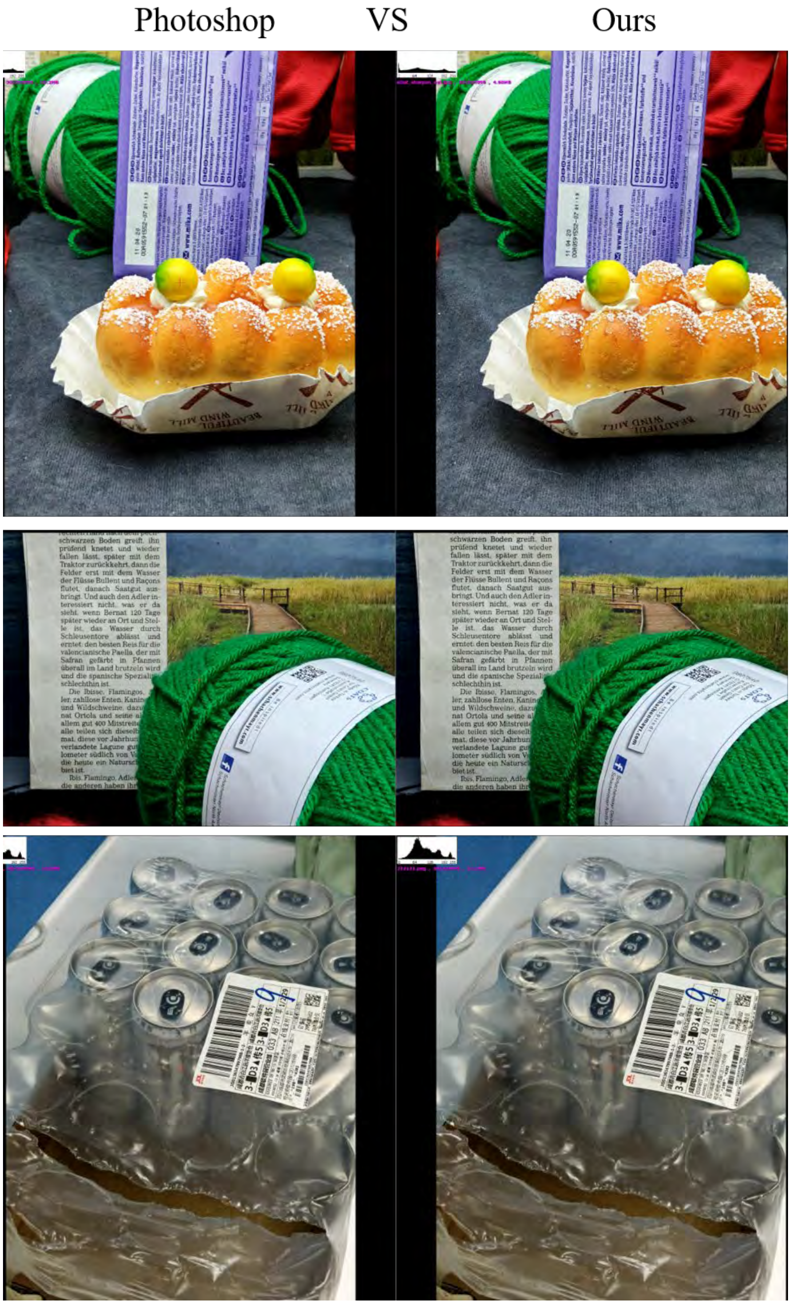
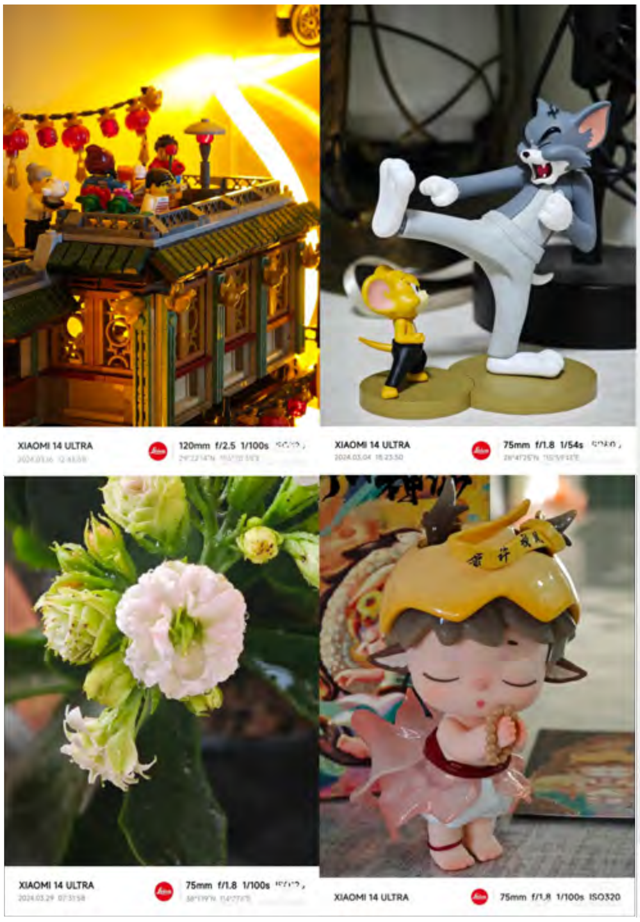
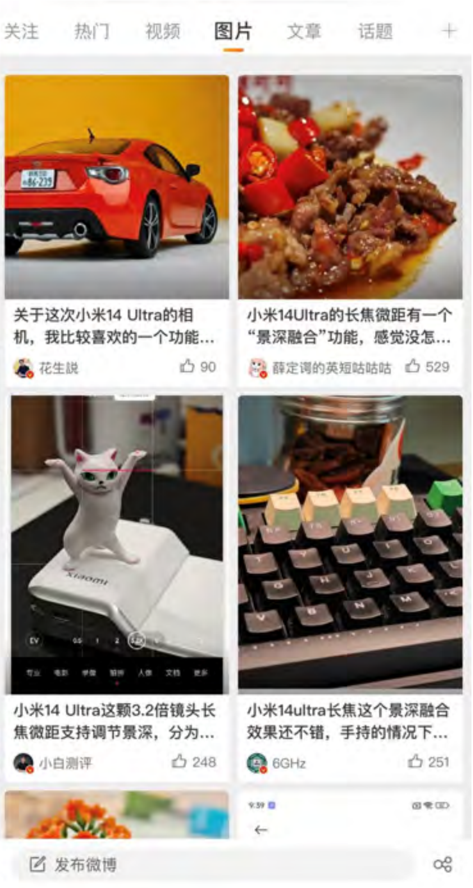


Fig. 5. Comparison between our eDof algorithm and Photoshop.

3 MEDIA REPORTS

With the release of the Xiaomi 14 Ultra, the eDof algorithm has received widespread acclaim on social media, as shown in Figure 6. I take great pride in seeing my algorithm being invoked repeatedly across millions of devices, bringing emotional resonance to consumers through imagery. This is a significant motivation and reason for my pursuit of a Ph.D.


XIAOMI 14 ULTRA
120mm f/2.5 1/100s
XIAOMI 14 ULTRA
75mm f/1.8 1/54s
XIAOMI 14 ULTRA
75mm f/1.8 1/100s
XIAOMI 14 ULTRA
75mm f/1.8 1/100s ISO320


关注
热门
视频
图片
文章
话题
+

关于这次小米14 Ultra的相机，我比较喜欢的一个功能…

花生説 90

小米14Ultra的长焦微距有一个"景深融合"功能，感觉没怎…

薛定谔的英短咕咕咕 529

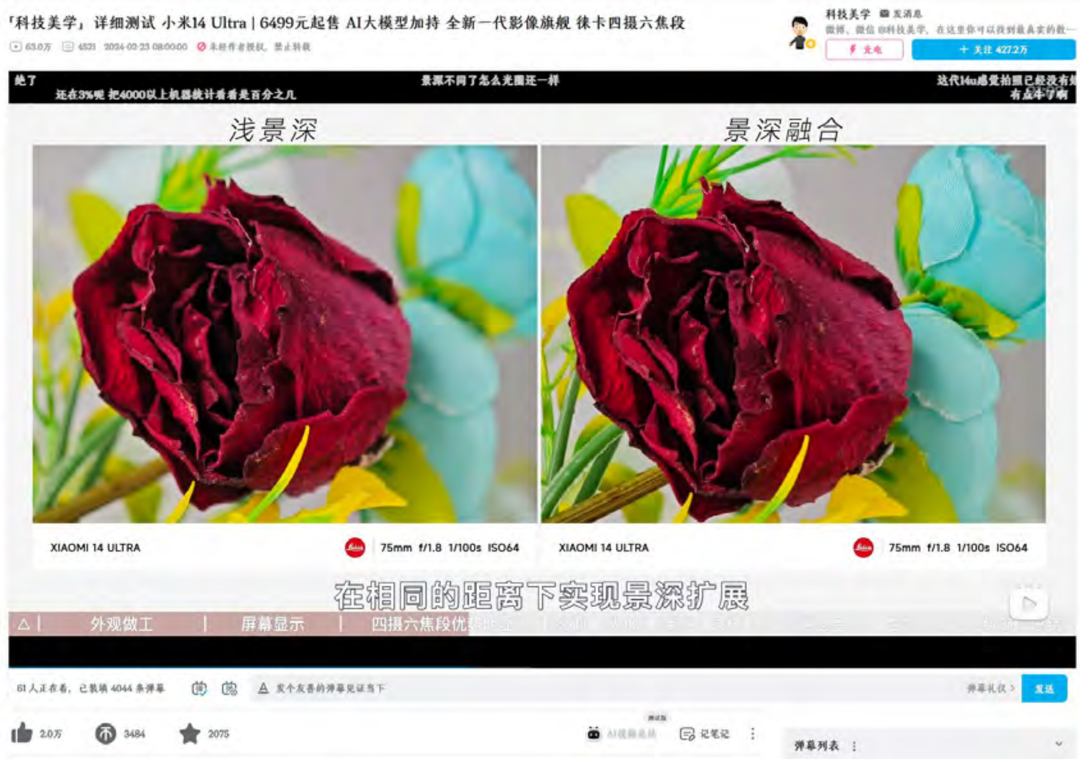
小米14 Ultra这颗3.2倍镜头长焦微距支持调节景深，分为…

小白测评 248

小米14ultra长焦这个景深融合效果还不错，手持的情况下…

6GHz 251

发布微博



「科技美学」详细测试 小米14 Ultra | 6499元起售 AI大模型加持 全新一代影像旗舰 徕卡四摄六焦段

63.0万 4521 2024-02-23 08:00:00 未经作者授权，禁止转载

科技美学 发消息

微博、微信 @科技美学，在这里你可以找到最真实的数…

充电
+ 关注 427.2万

绝了

还在3%呢 把4000以上机器统计看看是百分之几

景深不同了怎么光圈还一样

这代14u感觉拍照已经没有

有点牛了啊

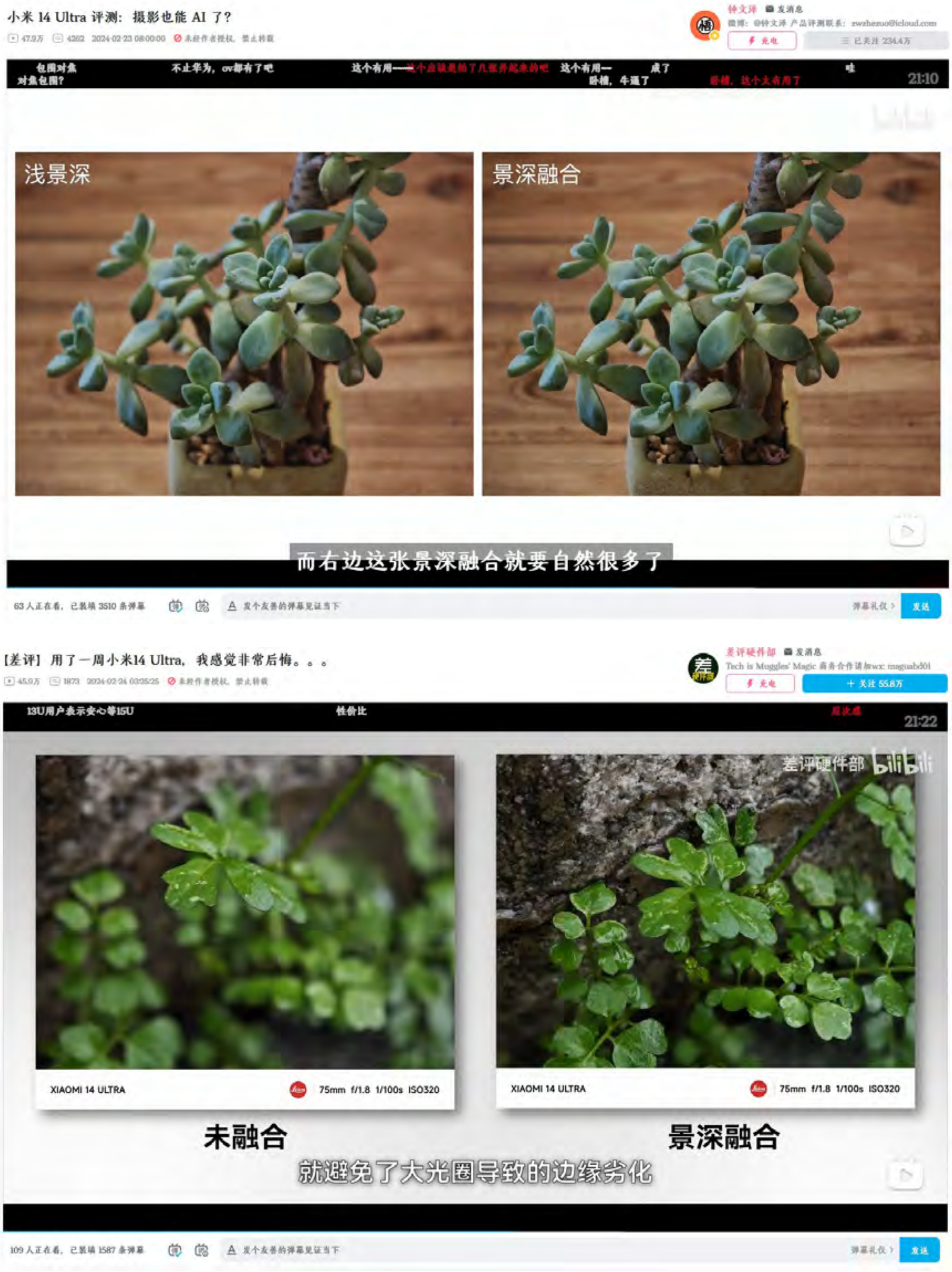
浅景深
景深融合
XIAOMI 14 ULTRA
75mm f/1.8 1/100s ISO64
XIAOMI 14 ULTRA
75mm f/1.8 1/100s ISO64

在相同的距离下实现景深扩展

外观做工
屏幕显示
四摄六焦段优

61 人正在看，已装填 4044 条弹幕

发个友善的弹幕见证当下
弹幕礼仪 >
发送
2.0万
3484
2075
记笔记
弹幕列表



小米 14 Ultra 评测：摄影也能 AI 了？

47.9万 4262 2024-02-23 08:00:00 未经作者授权，禁止转载

钟文泽

微博：@钟文泽 产品评测联系：zwzhezuo@icloud.com

包围对焦

对焦包围？

不止华为，ov都有了吧

这个有用——这个应该是拍了几张拼起来的吧

这个有用—

卧槽，牛逼了

成了

卧槽，这个太有用了

哇

浅景深

景深融合

而右边这张景深融合就要自然很多了

63 人正在看，已装填 3510 条弹幕

【差评】用了一周小米14 Ultra，我感觉非常后悔。。。

45.9万 1873 2024-02-24 03:25:25 未经作者授权，禁止转载

差评硬件部

Tech is Muggles' Magic 商务合作请加wx: maguabd01

13U用户表示安心等15U

性价比

层次感

未融合

景深融合

就避免了大光圈导致的边缘劣化

109 人正在看，已装填 1587 条弹幕

发消息
充电
已关注 234.4万
21:10
发个友善的弹幕见证当下
弹幕礼仪 >
发送
发消息
充电
+ 关注 55.8万
21:22
差评硬件部
bilibili
XIAOMI 14 ULTRA
75mm f/1.8 1/100s ISO320
XIAOMI 14 ULTRA
75mm f/1.8 1/100s ISO320
发个友善的弹幕见证当下
弹幕礼仪 >
发送

Fig. 6. Social media reviews of eDof in China, including platforms similar to Instagram, X, and YouTube.

[1] Teed Z, Deng J. Raft: Recurrent all-pairs field transforms for optical flow[C]//Computer Vision–ECCV 2020: 16th European Conference, Glasgow, UK, August 23–28, 2020, Proceedings, Part II 16. Springer International Publishing, 2020: 402-419.

[2] Ke B, Obukhov A, Huang S, et al. Repurposing diffusion-based image generators for monocular depth estimation[J]. arXiv preprint arXiv:2312.02145, 2023.